HERBIVOROUS INSECTS ASSOCIATED WITH THE PAPERBARK *MELALEUCA QUINQUENERVIA* AND ITS ALLIES: VI. PERGIDAE (HYMENOPTERA)

M.F. PURCELL[1] and J.A. GOOLSBY[2]

[1]*CSIRO Entomology, 120 Meiers Road, Indooroopilly, Qld 4068*

[2]*United States Department of Agriculture, Agricultural Research Service, Australian Biological Control Laboratory, c/- CSIRO Entomology, 120 Meiers Road, Indooroopilly, Qld 4068*

Abstract

Surveys were conducted in Australia to find biological control agents for the broad-leaved paperbark tree, *Melaleuca quinquenervia*, a serious pest in Florida, USA. This paper presents collection records and biological information for five sawfly species: *Acanthoperga cameronii* (Westwood), *Perga vollenhovii* Westwood, *Pergagrapta polita* Leach, *Pterygophorus insignis* Kirby and *Lophyrotoma zonalis* (Rohwer); all in family Pergidae. One of these species, *Lophyrotoma zonalis*, was extensively studied as a biological control agent but concerns over its toxicity have delayed release.

Introduction

Melaleuca quinquenervia (Cav.) S.T. Blake, the Australian broad-leaved paperbark tree, has become a serious pest in southern Florida, causing extensive economic and environmental damage. A history of surveys to find biological control agents for this tree and an overview of why it has become a serious pest in Florida are outlined in Rayamajhi *et al.* (2002). In five previous articles (Balciunas *et al.* 1993a, 1993b, 1995, Burrows *et al.* 1994, 1996), extensive collection and rearing records were presented for species of Lepidoptera belonging to the Noctuoidea, Geometridae, Gelechioidea, Tortricidae and Pyralidae and also limited records for other lepidopteran families. This paper continues the series and outlines the collection and rearing records of all species of Pergidae (Hymenoptera) found on broad-leaved *Melaleuca* species, as well as field observations and notes on the biology of each pergid species.

Methods

Collection methods were described in Balciunas *et al.* (1993a). All Pergidae recorded in this paper were collected and reared between 1987 and 2003. Observations on the biology and habits were made both in the field and laboratory. All larvae were reared on foliage of the tree species on which they were collected. Larvae of species of Perginae were placed into sealed plastic containers lined with paper towelling. Young foliage was provided as needed. When larvae became late instars, moist sand up to 5 cm deep was placed in the bottom of the container for pupation. Similar containers were used for Pterygophorinae species; however larvae were provided with older leaves while paper towelling or bark up to 5 cm deep was provided for pupation. The adult sawflies were identified by Dr Ian Naumann and Dr Stefan Schmidt (both formerly CSIRO Entomology) and Dr David Smith from the United States Department of Agriculture.

Voucher specimens are held at the Australian Biological Control Laboratory (ABCL), Brisbane, the Australian National Insect Collection (ANIC), Canberra and the United States Department of Agriculture (USDA), Systematic Entomology Laboratory, Washington D.C.

Collecting was concentrated in two coastal areas: from the Daintree River (north of Cairns) to Townsville in northern Queensland and from Hervey Bay in southern Queensland to Coffs Harbour in northern New South Wales. We also occasionally sampled sites outside these areas in Qld, NSW and the Northern Territory. The sites referred to in the text are listed below. Those marked with an asterisk (*) are either ornamental plantings or forest remnants in urban areas.

Northern Queensland: **Centenary Park***, Cairns (16°54.2'S 145°44.8'E) and **Cooktown Botanical Gardens*** (15°28.3'S 145°15.5'E).

Southern Queensland: **Boondall**, Brisbane (27°20.7'S 153°04.0'E); **Bracken Ridge**, Brisbane (27°20.0'S 153°01.9'E); **Bribie Island**, 49 km N of Brisbane (27°02.4'S 153°08.1'E); **Bribie Island Road**, 45 km N of Brisbane (27°04.6'S 153°00.6'E); **Bribie Island Tigers Club**, 45.8 km N of Brisbane (27°04.8'S 153°10.5'E); **Burpengary**, 34 km N of Brisbane (27°09.5'S 152°58.4'E); **Chelmer***, Brisbane (27°31.0'S 152°58.3'E); **Coolum**, 100 km N of Brisbane (26°34.1'S 153°05.5'E); **Deagon Deviation***, Brisbane (27°19.5'S 153°03.1'E); **Dickman Road***, 21 km S of Brisbane (27°39.5'S 152°59.8'E); **Ernest**, 62 km SE of Brisbane (27°04.6'S 153°00.6'E); **Fitzgibbon**, Brisbane (27°20.1'S 153°01.8'E); **Greenbank***, 26.5 km S of Brisbane (27°42.5'S 153°00.1'E); **Gumdale**, Brisbane (23°30.3'S 153°01.8'E); **Indooroopilly***, Brisbane (27°30.7'S 152°59.8'E); **Landsborough**, 74 km NNW of Brisbane (26°48.3'S 152°58.7'E); **Logan Sewerage Works***, 29 km SE of Brisbane (27°41.1'S 153°11.7'E); **Maroochydore Airport**, 95 km N of Brisbane (26°36.7'S 153°05.6'E); **Mountain Creek**, 85 km N of Brisbane (26°42.3'S 153°06.0'E); **Morayfield**, 45 km NNW of Brisbane (27°07.3'S 152°58.5'E); **North Pine Dam***, 29 km N of Brisbane (27°16.1'S 152°56.5'E); **Nudgee Nature Reserve**, 12.6 km NNE Brisbane (27°22.6'S 153°05.6'E); **Peregian Environmental Park**, 107 km N of Brisbane (26°30.4'S 153°05.5'E); **Poona National Park**, 212 km NNW of Brisbane (25°34.8'S 152°46.4'E); **Roy's Road**, 70 km N of Brisbane (26°51.1'S 152°59.4'E); **Sunnybank***, Brisbane (27°34.5'S 153°04.1'E); **Tibrogargen**, 60 km NNW of Brisbane (26°55.79'S 152°57.31'E) and **Woongoolba**, 42 km ESE of Brisbane (27°42.8'S 153°21.2'E).

New South Wales: **Queens Lake Nature Reserve**, 10 km SSW of Port Macquarie (31°37.8'S 152°49.6'E); **Lennox Head**, 123 km NNE of Grafton (28°44.8'S 153°35.8'E); **Maclean**, 39 km NE of Grafton (29°26.8'S 153°13.8'E); **Perch Hole**, 14 km SSW of Port Macquarie (31°29.8'S 152°54.1'E); **Sandy Beach**, 57 km SE of Grafton (30°09.4 153°11.5); **Tyagarah**, 136 km NNE Grafton (28°35.5'S 153°32.4'E); **Wamberal Lagoon Reserve**, 57 km N of Sydney (33°24.5'S 151°27.7'E); **White Tree Bay**, Myall Lakes (32°31.7'S 152°59.8'E); **Woodburn**, 62 km NE of Grafton (29°13.2'S 153°15.4'E) and **Yamba***, 50 km NE of Grafton (29°26.2'S 153°21.5'E).

Northern Territory: **Darwin City*** (12°27.7'S 130°50.4'E) and **East Charlotte River**, approx. 30 km S of Darwin (12°43'S 130°49'E).

Results

Collection and rearing records for all species of Pergidae collected in surveys of *Melaleuca* species are given in Table 1. The distribution of *Lophyrotoma zonalis* (Rohwer) and details of its biology and host range were detailed by Burrows and Balciunas (1997). Only new collection records for this species are listed.

Table 1. Pergidae sawflies reared from *Melaleuca quinquenervia* and six other myrtaceous tree species. Mlb = *M. leucadendra*, Mnd = *M. nodosa*, Mqn = *M. quinquenervia*, Mvr = *M. viridiflora*.

Species and Collection Site	Host Plant	Stage and No. Collected	Date Collected	Life History Information Pp = prepupal/pupal period
Subfamily Perginae (all species feed on young leaves)				
Acanthoperga cameronii				
Fitzgibbon	Mqn	30 larvae	28.vi.89	Preserved
Bracken Ridge	Mqn	19 larvae	5.vii.89	27 adults emerged 23.viii.-24.viii.89, pp=28-29 d
Bribie Island	Mqn	17 larvae	18.vii.89	7 adults emerged 16.x.-26.x.89
Tibrogargen	Mqn	14 larvae	18.vii.89	9 adults emerged 10.x.-26.x.89, pp=35-51 d
Gumdale	Mqn	No data	26.vii.89	No data
Gumdale	Mqn	12 larvae	5.ix.89	Died as immatures
Deagon Deviation	Mqn	No data	5.ix.89	No data
North Pine Dam	Mqn	28 larvae	9.xi.89	3 adults emerged 4-30.i.90, pp=30-56 d
Burpengary	Mqn	11 larvae	9.xi.89	Died as immatures
Greenbank	Mqn	15 larvae	10.xi.89	4 adults emerged 23.xii.89-2.i.90, pp 28-38 d
Burpengary	Mqn	10 larvae	20.xi.89	Died as immatures
Lennox Head	Mqn	35 larvae	20.iii.90	Died as immatures
Burpengary	Mqn	10 larvae	20.v.90	3 adults emerged
Fitzgibbon	Mqn	21 larvae	30.v.90	6 adults emerged 19-28.viii.90, pp=58-67 d
Burpengary	Mqn	19 larvae	1.viii.90	11 adults emerged 11-17.ix.90, pp=28-35 d
Boondall	Mqn	5 larvae	7.xi.90	2 adults emerged 12-14.xii.90, pp=30-32 d
Landsborough	Mqn	10 larvae	7.xi.90	No data
Ernest	Mqn	18 larvae	4.vi.91	Died as immatures
Morayfield	Mqn	14 larvae	29.x.92	9 adults emerged 17.xii.92-11.i.93, pp=18-43 d
Morayfield	Mqn	14 larvae	19.iv.93	Died as immatures
Morayfield	Mqn	1 larva	31.v.93	Died as immature
Morayfield	Mqn	30 larvae	21.vi.93	Died as immatures
Morayfield	Mqn	20 larvae	1.vii.93	Died as immature

Species and Collection Site	Host Plant	Stage and No. Collected	Date Collected	Life History Information Pp = prepupal/pupal period
Acanthoperga cameronii (continued)				
Morayfield	Mqn	22 larvae	26.vii.93	Adult emerged 4.ix.93
Morayfield	Mqn	13 larvae	2.viii.93	6 adults emerged 3.ix.-24.xii.93
Logan Sewerage Works	Mqn	18 larvae	1997	18 adults emerged
Roy's Road	Mqn	No data	1997	8 adults emerged
Maroochydore Airport	Mqn	5 larvae	1997	4 adults emerged
Maroochydore Airport	Mqn	27 larvae	2.vii.98	22 adults emerged 29.viii.-14.ix.98
Morayfield	Mqn	No data	15.vii.98	No data
Fitzgibbon	Mqn	No data	20.vii.98	No data
Coolum	Mqn	6 larvae	28.vii.98	6 adults emerged
Dickman Road	Mqn	Larvae, no data	17.xii.98	No data
Peregian Environmental Park	Mqn	30 larvae	10.viii.00	Died in rearing
Queens Lake Nature Reserve	Mqn	25 larvae	1.xi.00	5 adults emerged
Perch Hole	Mqn	Larvae, no data	1.viii.01	7 adults emerged 20-24.ix.01
Roy's Road	Mqn	15 larvae	5.xi.02	No data
Perga vollenhovii				
Centenary Park	Mlb	50 larvae	13.vii.87	Adult emerged
Centenary Park	Mlb	24 larvae	3.viii.87	15 adults emerged 6.ix.-14.ix.87
Centenary Park	Mlb	114 larvae	29.vii.88	14 adults emerged 5.ix.-8.ix.88
Cooktown Botanical Gardens	Mlb	30 larvae	27.viii.88	No data
Centenary Park	Mlb	9 larvae	10.vii.89	No data
Pergagrapta polita				
Sunnybank	Mqn	1 larva	5.x.87	Preserved
Tibrogargen	Mqn	24 larvae	7.vi.88	4 adults emerged 25.x.-27.x.88
Sandy Beach	Mqn	14 larvae	18.viii.88	3 adults emerged 1.xi.88
Bribie Island Road	Mqn	60 larvae	19.viii.88	34 adults emerged 20.x.-14.xi.88, pp=58-83 d
Bracken Ridge	Mqn	11 larvae	19.viii.88	11 adults emerged 7.xi.88-12.i.89, pp=37-102 d
Gumdale	Mqn	60 larvae	26.vii.89	8 adults emerged 23.x.-2.xi.89
Gumdale	Mqn	12 larvae	5.ix.89	Adult emerged 27.iii.90, pp=198 d
Fitzgibbon	Mqn	23 larvae	30.v.90	Died as immatures

Species and Collection Site	Host Plant	Stage and No. Collected	Date Collected	Life History Information Pp = prepupal/pupal period
Pergagrapta polita (continued)				
Deagon Deviation	Mqn	6 larvae	6.vi.90	2 adults emerged 28.iii.91, pp=231 d
Gumdale	Mqn	18 larvae	1.viii.90	Died as immatures
Yamba	Mqn	11 larvae	11.ix.90	10 adults emerged 19-23.x.90, pp=24-28 d
Lennox Head	Mqn	8 larvae	11.ix.90	Died as immatures
Boondall	Mqn	10 larvae	15.vii.92	7 adults emerged 8.iii.93
Lennox Head	Mqn	8 larvae	3.viii.00	Adult emerged 5-6.x.00
Mountain Creek	Mqn	200 larvae	10.viii.00	8 adults emerged 16-27.x.00
Mountain Creek	Mqn	Larvae, no data	9.x.00	No data
Subfamily Pterygophorinae (both species feed on leaves)				
Pterygophorus insignis				
Maclean	Mqn	1 larva	15.iii.88	Preserved
North Pine Dam	Mqn	24 larvae	15.xi.88	Preserved
Indooroopilly	Mqn	29 larvae	2.i.90	Died as immatures
Burpengary	Mqn	19 larvae	3.i.90	Died as immatures
Fitzgibbon	Mqn	10 larvae	3.i.90	Died as immatures
Burpengary	Mqn	14 larvae	23.i.90	Adult male emerged 16.iii.90
Fitzgibbon	Mqn	13 larvae	23.i.90	Died as immatures
Lennox Head	Mqn	17 eggs	20.iii.90	Died as immatures
Coolum	Mqn	95 larvae	1.v.90	7 adults emerged 25.vii.90-23.i.91 pp=69 d [1 individual only]
Fitzgibbon	Mqn	42 larvae	10.v.90	Died as immatures
Fitzgibbon	Mqn	2 larvae	20.v.90	2 adults emerged 27-28.viii.90, pp= 80-81 d
Fitzgibbon	Mqn	1 larva	30.v.90	Died as immature
Indooroopilly	Mqn	23 larvae	10.v.91	2 adults emerged 6.ix.-14.x.91
Ernest	Mqn	2 larvae	4.vi.91	Died as immatures
Chelmer	Mqn	1 larva	29.vii.91	No data
Indooroopilly	Mnd	10 larvae	13.ii.92	2 adults emerged
Indooroopilly	Mqn	Adult	15.iv.92	Preserved
Fitzgibbon	Mqn	20 larvae	26.v.92	3 adults emerged 17.vii.-10.viii.92, pp=16-40 d
Chelmer	Mqn	12 larvae	31.v.92	Died as immatures
Coolum	Mqn	6 larvae	22.vi.92	4 adults emerged 5.viii.-10.viii.92, pp=13-17 d
Chelmer	Mqn	1 larva	1.vii.92	Adult emerged 17.viii.92, pp=66 d
Indooroopilly	Mqn	1 larva	17.xii.92	Died as immature
Morayfield	Mqn	35 larvae	20.i.93	Died as immatures

Species and Collection Site	Host Plant	Stage and No. Collected	Date Collected	Life History Information Pp = prepupal/pupal period
Pterygophorus insignis (continued)				
Indooroopilly	Mqn	16 larvae	8.ii.93	5 adults emerged
Coolum	Mqn	15 larvae	31.iii.93	Died as immatures
Indooroopilly	Mqn	14 larvae	1.iv.93	Died as immatures
Morayfield	Mqn	1 larva	29.iv.93	Died as immature
Morayfield	Mqn	1 larva	6.v.93	Died as immature
Indooroopilly	Mqn	8 larvae	14.xii.93	Died as immatures
Coolum	Mqn	7 larvae	7.iii.94	Died as immatures
Morayfield	Mqn	No data	27.vii.95	Field observation
Woodburn	Mqn	1 larva	8.iv.97	Adult emerged
Logan Sewerage Works	Mqn	1 larva	19.v.97	Adult emerged
Tayagarah	Mqn	2 larva	xii.97	2 adults emerged
Wamberal Lagoon Reserve	Mqn	22 larvae	14.x.99	Died as immatures
Woongoolba	Mqn	3 larvae	16.xii.99	Adult emerged
Roy's Road	Mqn	11 larvae	30.iii.00	Died as immatures
Peregian Environmental Park	Mqn	11 larvae	30.iii.00	Died as immatures
Roy's Road	Mqn	7 larvae	19.iv.00	5 died as immatures, 2 preserved
Roy's Road	Mqn	1 larva	16.vi.00	Preserved
White Tree Bay	Mqn	20 larvae	31.x.00	Preserved
Poona National Park	Mqn	7 larvae	5.xii.00	Died in rearing
Indooroopilly	Mqn	Larvae, no data	3.v.01	Adult emerged
Nudgee Nature Reserve	Mqn	15 larvae	31.i.02	5 adults emerged
Poona National Park	Mqn	5 larvae	30.v.02	Adult emerged 6.viii.02
Lophyrotoma zonalis				
Darwin	Mlb	30 larvae	19.iv.93	6 adults emerged 19-24.v.93
East Charlotte River	Mvr	17 larvae	11.xi.98	Died as immatures
Bribie Island Tigers Club	Mlb	53 larvae	4.iii.04	50 died in rearing, 3 preserved
Bribie Island Tigers Club	Mlb	9 adults	1.iv.04	Preserved

Discussion

Pest status

Of the five sawfly species collected by ABCL staff from broad-leaved *Melaleuca* species in Queensland, New South Wales and the Northern Territory, only two species have been recorded elsewhere as a pest of *Melaleuca*. Jones and Elliot (1990) listed a paperbark sawfly species in tropical and subtropical regions of Australia that attacked *M. leucadendra*, *M. quinquenervia* and *M. viridiflora*. It was listed as a gregarious species that riddled the papery bark with holes. Although the species was not identified, it is likely to be *Lophyrotoma zonalis*, the only species which pupates by

burrowing into the soft, papery bark of broad-leaved *Melaleuca* trees. *Pterygophorus insignis* Kirby, also known as the long-tailed sawfly, is a very destructive pest of *Callistemon* and also feeds on *Leptospermum* spp. and *Melaleuca armillaris* Smith (Jones and Elliott 1990).

Distribution and host plants

Our records for *L. zonalis* now include Bribie Island in southeast Queensland. Burrows and Balciunas (1997) listed Mackay, on the central Queensland coast, as the southernmost range of this species. Its appearance on Bribie Island, 900 km south of Mackay, appears to be isolated as no other infestations in this region have been observed in over 17 years of collections. We suspect an introduction into this area from its normal range has occurred, possibly via the nursery trade. We also collected *L. zonalis* from two locations in the Northern Territory: Darwin and the East Charlotte River. Burrows and Balciunas (1997) listed only literature records and no collections from this region. *Acanthoperga cameronii* (Westwood), *Pergagrapta polita* Leach and *Pterygophorus insignis* were only collected in southeast Queensland and New South Wales, while *Perga vollenhovii* Westwood was restricted to the tropical region between Cairns and Cooktown, although it has been recorded as far south as New South Wales (Benson 1939). *Acanthoperga cameronii* (Westwood) appears to be highly specific and was only collected from *M. quinquenervia*, while *Perga vollenhovii* was only recorded on *M. leucadendra*. We collected *Pergagrapta polita* from *M. quinquenervia*, although it is known to have many *Eucalyptus* and *Angophora* hosts (S. Schmidt pers. comm.). *Pterygophorus insignis* larvae were collected from *M. quinquenervia* and *M. nodosa* (Gaertn.) Smith in southeast Queensland.

Biology

Acanthoperga cameronii was the only species (excluding *L. zonalis*) that oviposited on potted saplings in the laboratory. Parthenogenesis was observed, with the female ovipositing 29 eggs into young plant tissue along the midvein on one side of a leaf. All eggs hatched together after 12 days and the neonate larvae formed a circular, gregarious feeding group on the young leaf. As they became larger, the larvae fed as a front along both sides of the young leaves. The larval duration for these laboratory generated immatures was 48 days (n=27) and the prepupal/pupal duration ranged from 48-135 days (n=7).

The habits and biology of immatures of both *A. cameronii* and *Pergagrapta polita* are very similar. Feeding occurs at night and only on young foliage. During the day larvae move away from this foliage to a lower twig or branch (aggregation sites), forming a gregarious mass. Hundreds of larvae have been observed in these groups, which often varied in age structure. Damage is distinctive at field sites where the tops of trees are completely defoliated. When larvae are disturbed, they raise their head and abdomen and regurgitate

plant host oils as a defence mechanism. Regurgitation may also be used to eliminate oils from their diet to reduce the toxicity of their food plants (Schmidt *et al.* 2000). This orange coloured, viscous liquid drips from the larval masses in large quantities, which can stain the bark of the host tree. This defensive behaviour has been recorded for other species of Perginae (Carne 1962, Macdonald and Ohmart 1993). Leadership behaviour appears to occur with larvae following a leader to feeding sites or aggregation sites. Larvae move as a gregarious mass into the soil to pupate. Each larva forms an individual pupal capsule, most likely made of sand particles, faecal matter, silk and material from the repugnatorial gland (Macdonald and Ohmart 1993). The pupal capsules are divided into two chambers, separating the prepupae/pupae from the exuviae of the last larval moult. The pupal duration for field collected *A. cameronii* and *P. polita* ranged from 18-67 days and 58-231 days respectively. Both species were parasitised by tachinid flies. Emerging adults of both species are strong fliers, with males smaller than females. The larvae and adults of both species are brown, although the late instar larvae and adults of *P. polita* are both darker and larger than those of *A. cameronii*. The late instar larvae and adults of both species can be separated definitively by the cream coloured markings on the dorsal thoracic segments of *P. polita*, which are absent on *A. cameronii*.

The habits of *Perga vollenhovii* are largely unknown, although the larvae form gregarious masses and feed on young foliage, as in the other two species of Perginae. In the laboratory, the prepupal/pupal duration is approximately 4-6 weeks. Larvae, which were collected from only two sites in the months of July or August, were frequently parasitised by *Froggattimyia* Townsend sp. (Diptera: Tachinidae). Eighty percent of larvae were parasitized in one collection from Centenary Park in Cairns.

Pterygophorus insignis has habits which are very similar to those of *L. zonalis*, outlined in Burrows and Balciunas (1997). Larvae of both species appear identical. Adults of both species are similar, being black in colour with gold markings on the dorsal surface of the thorax and also on segments of the abdomen. However, the gold banding of the abdomen differs between the species. On *L. zonalis* abdominal segments 2-5 are gold, while on *P. insignis* only segments 2 and 3 are this colour. *P. insignis* also has gold markings on abdominal segment 7; these are absent on *L. zonalis*. Females are parthenogenic and lay batches of eggs along the margin of leaves. Larvae hatch and form a feeding front along both sides of the leaf, initially causing skeletonisation, followed by consumption of the whole leaf as the larvae mature. In later instars, the larvae feed individually or in groups of 2-3. Larvae feed throughout the day. Unlike *L. zonalis*, there are no distinctive pupation holes in the bark of the host tree and no pupae were found in the field. In the laboratory, pupation occurred in paper towelling or in paperbark from the host tree held in plastic containers. The prepupal/pupal duration ranged from 13-81 days.

Biological control

Only *Lophyrotoma zonalis* was considered as a biological control agent for *M. quinquenervia*. Because this sawfly pupates in the bark of the host tree, it will be able to complete its life cycle in the wetland areas of southern Florida, where *M. quinquenervia* is a serious weed. These areas are mostly permanently or seasonally inundated and any pupae beneath the soil would drown during flooding. The remaining four sawfly species collected in our surveys all pupate in the soil and would therefore be limited in their potential to build up sufficiently large populations to damage trees. They could only be effective in drier areas that were, at best, seasonally inundated, allowing immatures to complete their development. The field host ranges of *Pterygophorus insignis* and *Pergagrapta polita* are also too broad for biological control.

The three pergine species, *Acanthoperga cameronii*, *P. polita* and *Perga vollenhovii*, feed on young foliage, which is only produced seasonally following flowering. As in other members of this subfamily, these sawflies are likely to remain in a static condition as prepupae beneath the soil between seasons or longer (Macdonald and Ohmart 1993), leaving them exposed over long periods to possible flooding. Our longest prepupal/pupal duration for *A. cameronii* and *P. polita* was 135 days and 231 days respectively. Additionally, attacking the young foliage of *M. quinquenervia* in Florida is already being successfully addressed by the foliage feeding weevil *Oxyops vitiosa* Pascoe (Coleoptera: Curculionidae) and the sap-sucking psyllid *Boreioglycaspis melaleucae* Moore (Hemiptera: Psyllidae), released in Florida in 1997 (Center *et al.* 2000) and 2002 (Wood and Flores 2002) respectively.

Quarantine testing of *L. zonalis* has been completed in the United States and its host range is considered to be sufficiently narrow for release as a biological control agent. However, a related sawfly, *L. interrupta* Klug, has been implicated in cattle poisonings in a small area of southwestern Queensland (Roberts 1932, Dadswell *et al.* 1985, McKenzie *et al.* 1985a). The epidemiology and the possible causes of these poisonings are outlined in several studies (Oelrichs 1982, Dadswell *et al.* 1985, McKenzie *et al.* 1985b). Sawfly poisonings have also been recorded more recently on two other continents. In Europe, *Arge pullata* Zaddach (Argidae), the birch tree sawfly, has poisoned sheep and goats in Denmark (Thamsborg *et al.* 1987), while *Perreyia flavipes* Konow (Pergidae) has poisoned cattle and sheep in Uruguay, South America (Dutra *et al.* 1997, Riet-Correa *et al.* 1998). Two peptides, lophyrotomin and pergidin, have been isolated and identified as the toxins in these sawflies and the quantities of each peptide vary between the species (Oelrichs *et al.* 1999, 2001).

Lophyrotoma zonalis sawflies from the quarantine culture in Florida were sent to Dr Oelrichs for testing. Both peptides were isolated and both were

toxic to mice (Oelrichs *et al.* 2001). Even though large numbers of *L. zonalis* can be found defoliating *Melaleuca* trees in Queensland and the Northern Territory, there are no recorded incidences of livestock being poisoned. There are also differences between the larval habits of *L. zonalis* and those of other sawflies that have been implicated in animal poisonings around the world.

Unlike these other sawflies, *L. zonalis* larvae pupate individually in the papery bark of *Melaleuca* trees, inaccessible to many animals, especially livestock. The sawflies involved in cattle poisoning pupate in the soil and are accessible to livestock. Species like *L. interrupta* form large gregarious masses at ground level on which the cattle feed. If *L. zonalis* were released in Florida, the major concern would be for birds, reptiles and small mammals which could access the larvae in the trees. However, as a defence mechanism, the larvae of *L. zonalis* regurgitate fluid that possibly contains, or has been derived from, high concentrations of essential oils found in the leaves of *Melaleuca*. Therefore, they may be unpalatable to many of these animals. However, many starving migratory birds arrive in Florida after long flights over open water and, through desperation, may feed on them (T. Center pers comm.). Therefore, planned release of this agent has been temporarily abandoned. Toxicity trials using whole larvae may be performed in future.

Information on the toxic effects of agents for biological control of weeds is rarely considered when candidates are being evaluated. Only two sawflies have been released as biological control agents (Julien and Griffiths 1998) and both are from the family Tenthredinidae. Biological control practitioners should be aware that any sawflies being evaluated as agents should be assessed for toxicity, considering that poisoning by sawflies from two families has occurred on three continents (Oelrichs *et al.* 1999).

Acknowledgements

We thank G.J. Bowman, D. Burrows, B. Brown, L.M. Brown, K.E. Galway, P.K. Jones, J.R. Makinson, C.R. Maycock and S.J. Miller for help in collecting and rearing insects. This study was funded by USA Federal and State of Florida Agencies: USDA-ARS-Office of International Research Programs; US Army Corps of Engineers (Jacksonville District); National Park Service; Florida Department of Environmental Protection; South Florida Water Management District; Lee and Dade Counties, Florida.

References

BALCIUNAS, J.K., BOWMAN, G.J. and EDWARDS, E.D. 1993a. Herbivorous insects associated with the paperbark *Melaleuca quinquenervia* and its allies: I. Noctuoidea (Lepidoptera). *Australian Entomologist* **20**: 13-24.

BALCIUNAS, J.K., BURROWS, D.W. and EDWARDS, E.D. 1993b. Herbivorous insects associated with the paperbark *Melaleuca quinquenervia* and its allies: II. Geometridae (Lepidoptera). *Australian Entomologist* **20**: 91-98.

BALCIUNAS, J.K., BURROWS, D.W. and HORAK, M. 1995. Herbivorous insects associated with the paperbark *Melaleuca quinquenervia* and its allies: IV. Tortricidae (Lepidoptera). *Australian Entomologist* **22**: 125-135.

BENSON, R.B. 1939. A revision of the Australian sawflies of the genus *Perga* Leach, sens. lat. (Hymenoptera, Symphyta). *Australian Zoologist* **9**(3): 324-357.

BURROWS, D.W. and BALCIUNAS, J.K. 1997. Biology, distribution and host-range of the sawfly, *Lophyrotoma zonalis* (Hym., Pergidae), a potential biological control agent for the paperbark tree, *Melaleuca quinquenervia*. *Entomophaga* **42:** 299-313.

BURROWS, D.W., BALCIUNAS, J.K. and EDWARDS, E.D. 1994. Herbivorous insects associated with the paperbark *Melaleuca quinquenervia* and its allies: III. Gelechioidea (Lepidoptera). *Australian Entomologist* **21**: 137-142.

BURROWS, D.W., BALCIUNAS, J.K., and EDWARDS, E.D. 1996. Herbivorous insects associated with the paperbark *Melaleuca quinquenervia* and its allies: V. Pyralidae and other Lepidoptera. *Australian Entomologist* **23**: 7-16.

CARNE, P.B. 1962. The characteristics and behaviour of the saw-fly, *Perga affinis affinis* (Hymenoptera). *Australian Journal of Zoology* **10**: 1-34.

CENTER, T.D., VAN, T.K., RAYACHHETRY, M., BUCKINGHAM, G.R., DRAY, F.A., WINERITER, S.A., PURCELL, M.F. and PRATT, P.D. 2000. Field colonization of the melaleuca snout beetle (*Oxyops vitiosa*) in south Florida. *Biological Control* **19**: 112-123.

DADSWELL, L.P., ABBOTT, W.D. and MCKENZIE, R.A. 1985. The occurrence, cost and control of sawfly larval (*Lophyrotoma interrupta*) poisoning of cattle in Queensland 1972-1981. *Australian Veterinary Journal* **62**: 94-97.

DUTRA, F., RIET-CORREA, F., MENDEZ, M.C. and PAIVA, N. 1997. Poisoning of cattle and sheep in Uruguay by sawfly (*Perreyia flavipes*) larvae. *Veterinary and Human Toxicology* **39**: 281.

JONES, D.L. and ELLIOT, W.R. 1990. *Pests, diseases and ailments of Australian plants*. Lothian Publishing, Melbourne; 333 pp.

JULIEN, M.H. and GRIFFITHS, M.W. (eds). 1998. *Biological control of weeds: a World catalogue of agents and their target weeds*. CAB International, Wallingford; 223 pp.

MACDONALD, J. and OHMART, C.P. 1993. Life history strategies of Australian pergid sawflies and their interactions with host plants. Pp 485-502, in: Wagner, M.R. and Raffa, K.F. (eds). *Sawfly life history and adaptations to woody plants*. Academic Press, California; 581pp.

MCKENZIE, R.A., ROGERS, R.J. and OELRICHS, P.B. 1985a. Sawfly larval poisoning of cattle in Queensland. Pp 524-532, in: Seawright, A.A., Hegarty, M.P., James, L.F. and Keeler, R.F. (eds), *Proceedings of the Australia - U.S.A. poisonous plants symposium*, 14-18 May 1984, Brisbane, Australia. Queensland Department of Primary Industries, Brisbane; 596 pp.

MCKENZIE, R.A., DUNSTER, P.J., TWIST, J.O., DIMMOCK, C.K., OELRICHS, P.B., ROGERS, P.J. and REICHMANN, K.G. 1985b. *The toxicity of sawfly larvae (*Lophyrotoma interrupta*) to cattle.* Queensland Department of Primary Industries, QB85001; 48 pp.

OELRICHS, P.B. 1982. Sawfly poisoning of cattle. *Queensland Agricultural Journal* **108**: 110-112.

OELRICHS, P. B., MACLEOD, J.K., SEAWRIGHT, A.A. and GRACE, P.B. 2001. Isolation and identification of the toxic peptides from *Lophyrotoma zonalis* (Pergidae) sawfly larvae. *Toxicon* **39**: 1933-1936.

OELRICHS, P.B., MACLEOD, J.K., SEAWRIGHT, A.A., MOORE, M.R., NG, J.C., DUTRA, F., RIET-CORREA, F., MENDEZ, M.C. and THAMSBORG, S.M. 1999. Unique toxic peptides isolated from sawfly larvae in three continents. *Toxicon* **37**: 537-544.

RAYAMAJHI, M.B., PURCELL, M.F., VAN, T.K., CENTER, T.D., PRATT, P.D. and BUCKINGHAM, G.R. 2002. 8, Australian paperbark tree (*Melaleuca*). Pp 117-130, in: Van Driesche, R., Blossey, B., Hoddle, M. and Reardon R. (eds), *Biological control of invasive plants in the eastern United States, Section II: Weeds of wetlands*. USDA Forest Service Publication FHTET-2002-04; 413 pp.

RIET-CORREA, F., DUTRA, F., SOARES, M.P. and MENDEZ, M.C. 1998. Sawfly (*Perreyia flavipes*) larval poisoning in cattle, sheep and swine. Pp 291-296, in: Garland, T. and Barr, A.C. (eds), *Toxic plants and other natural toxicants*. CAB International, Wallingford; 608 pp.

ROBERTS, F.H.S. 1932. The cattle-poisoning sawfly (*Pterygophorus analis*). *Queensland Agricultural Journal* **37:** 41-52.

SCHMIDT, S., WALTER, G.H. and MOORE, C.J. 2000. Host plant adaptations in myrtaceous-feeding pergid sawflies: essential oils and the morphology and behaviour of *Pergagrapta* larvae (Hymenoptera, Symphyta, Pergidae). *Biological Journal of the Linnean Society* **70**(1): 15-26.

THAMSBORG, S.M., JORGENSEN, R.J., and BRUMMERSTEDT, E. 1987. Sawfly poisoning in sheep and goats. *The Veterinary Record* **121**: 253-255.

WOOD, M. and FLORES, A. 2002. Sap-sucking psyllid pesters pushy plant. *Aquatics* **50**(11): 18-19.